

## Web Material

### **Title: Estimates of Childhood Overweight and Obesity at the Region, State, and County Levels: A Multilevel Small Area Estimation Approach**

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## Web Appendix 1: Small Area Estimation (SAE) Model

Let  $y_{jk}$  be the overweight/obesity indicator (yes/no) for child  $j$  in county  $k$ , where  $y_{jk}$  has a Bernoulli distribution  $y_{jk} \sim \text{Bernoulli}(p_{jk})$ , where  $\text{logit}(p_{jk}) = \log\left(\frac{p_{jk}}{1-p_{jk}}\right)$ , as well as  $p_{jk} = P(y_{jk} = \text{yes})$ . Our mixed-effects model can then be written as:

$$\text{logit}(p_{jk}) = \mathbf{X}_{jk}\boldsymbol{\beta}^{[1]} + \mathbf{C}_k\boldsymbol{\beta}^{[2]} + b_k$$

where  $\mathbf{X}_{jk}$  represented the child-level fixed-effects covariates (race/ethnicity, age, gender, parents' highest educational attainment),  $\mathbf{C}_k$  represented the area-level fixed-effects covariates (Census regional division, rate of children living in households with a single parent in 2015, number of primary care providers per 100,000 residents in the county in 2016, county adult obesity rate in 2015, presence of a school wellness policy at the state level in 2016, weighted walkability index according to the county population distribution in 2016, and rurality status as determined by the 2013 Urban Influence Codes), and  $b_k$  represented the spatial random intercept for county  $k$  where  $b_k$  was modeled using an intrinsic conditional autoregressive (ICAR) model. An ICAR model implies that  $b_k | \mathbf{b}_{-k} \sim N(\bar{b}_k, \sigma^2/n_k)$ , where  $\mathbf{b}_{-k}$  represents the random intercepts of all counties excluding county  $k$ ,  $\bar{b}_k$  is the average random intercept for counties that neighbor county  $k$ , and  $n_k$  the number of neighbors of county  $k$  (1,2). To implement this model, SAS PROC GLIMMIX was used. The vector of random intercepts for all counties has distribution  $\mathbf{b} \sim \text{MVN}(0, \sigma^2 \mathbf{Q}^{-1})$ , where  $\mathbf{Q}$  is a precision matrix with diagonal entries  $n_k$  and off-diagonal entries  $w_{k,k'}$  where  $w_{k,k'}$  and  $w_{k',k}$  equal to  $-1$  when counties  $k$  and  $k'$  are neighbors and zero otherwise and  $\sigma^2$  the variance parameter for the random effect (3).

The covariates used in the final model were selected using five-fold cross-validation. This approach involved randomly splitting the dataset into five groups of approximately equal size. Each fold was sequentially used as a validation set while the remaining four folds were used to train the model (4–6). The model fitted on the training set was used to predict the probability of overweight/obesity on the validation set, and Root Mean Squared Prediction Error (RMSPE) was estimated. The five RMSPEs were averaged and the model providing the smallest average RMSPE was selected.

## Post-Stratification

Our multilevel mixed-effects ICAR logistic regression model resulted in estimates of prevalence for each county for all 256 levels (strata) of the child-level variables (4 race/ethnicity levels, 2 gender levels, 8 age levels, and 4 education levels) denoted as  $\hat{p}_{rgaek}$  for county  $k$  and strata level  $r$ ,  $g$ ,  $a$ , and  $e$  for race/ethnicity, gender, age, and education, respectively. In order to create a single county-level estimate from the 256 strata specific county-level estimates, we conducted post-stratification where

$$\hat{p}_k = \frac{\sum_r \sum_g \sum_a \sum_e \hat{p}_{rgaek} \text{POP}_{rgaek}}{\sum_r \sum_g \sum_a \sum_e \text{POP}_{rgaek}}$$

and where  $\text{POP}_{rgaek}$  was the population of children in strata level  $r$ ,  $g$ ,  $a$ , and  $e$  in county  $k$  (7). This step ensured each county's obesity estimate reflected the underlying population distribution by race/ethnicity, age, gender, and parent's educational attainment.

Census population estimates (or equivalently prevalence estimates) for the various strata of race/ethnicity, age, gender, and parent's educational attainment were not publicly available. Thus, to estimate the prevalence of race/ethnicity, age, gender, and education strata  $r$ ,  $g$ ,  $a$ , and  $e$ , respectively, for county  $k$  (denoted by  $P_k(rgae)$ ), we used a combination of Census data and of 2016 National Survey of Children's Health (NSCH) public-use data. Let  $P_k(e|rga)$  denote the prevalence of education level  $e$  given race/ethnicity, age, and gender strata  $r$ ,  $g$ , and  $a$ . Using conditional probability:

$$P_k(rgae) = P_k(e|rga)P_k(rga),$$

where  $P_k(rga)$  was available from Census data (age was grouped into 10-14 years old, 15-17 years old). We assumed that a parent's education is independent of the child's gender and age, i.e.,  $P_k(e|rga) = P_k(e|r)$ . Census data on race/ethnicity by highest education for adults was available at the county and state levels, however, it used all adults (instead of parents only) and was the highest education of a single adult (instead of the highest of the child's parent(s)).

Thus, the census data was a different population. We denoted the census prevalence estimates by  $P_k(e_A|r)$  and  $P_{S(k)}(e_A|r)$  which are the prevalence of education level  $e$  given race/ethnicity level  $r$  among adults in county  $k$  and state  $S$  of county  $k$ , respectively. We assumed that the ratio of county to state prevalence were equal to the same ratio for parents:

$$Q_{erk} = \frac{P_k(e_A|r)}{P_{S(k)}(e_A|r)} = \frac{P_k(e|r)}{P_{S(k)}(e|r)}.$$

For example, suppose county  $k$  had twice the prevalence of Hispanic adults with a college degree than the state of county  $k$ . We assumed that in this county  $k$ , the prevalence of Hispanic children whose parent(s)'s highest education level was a college degree was two times the state prevalence of Hispanic children whose parent(s)'s highest education level was a college degree. Under this assumption, the desired prevalence is given by

$$P_k(e|r) = Q_{erk} * P_{S(k)}(e|r).$$

Here,  $Q_{erk}$  can be calculated from the Census data. Further,  $P_{S(k)}(e|r)$ , can be estimated using the publicly available 2016 NSCH dataset with a mixed-effects multinomial regression model of parent's educational attainment as a function of race, Census regional division, and a random state-level intercept (county was unavailable in the public NSCH data). Using this multinomial model, we predicted  $P_{S(k)}(e|r)$ , the probability of attainment for each education, race, and state combination. We could then calculate  $P_k(e|r)$ . Using  $P_k(e|r)$ , we could multiply it with  $POP_{rgak}$ , population of children in strata level  $r$ ,  $g$ , and  $a$  in county  $k$ , to get  $POP_{rgaek}$ , and complete the bootstrapping procedure.

## Bootstrap Procedure

To estimate the variability in the estimated obesity rates, we used a Monte Carlo-based parametric bootstrapping approach. With this approach, we formulated confidence intervals (CI) for county-level obesity prevalence rates. The bootstrap procedure was repeated for 10,000 iterations. At each iteration  $rep$ , we drew regression coefficients  $\tilde{\beta}^{rep}$  from a normal distribution using estimated regression coefficients and their covariance:

$$\tilde{\beta}^{rep} \sim N(\hat{\beta}, \hat{\Sigma}_{\hat{\beta}})$$

Note that  $\tilde{\boldsymbol{\beta}}^{rep} = [\tilde{\boldsymbol{\beta}}^{[1],rep} \tilde{\boldsymbol{\beta}}^{[2],rep}] \cdot \hat{\boldsymbol{\beta}}$  and  $\hat{\boldsymbol{\Sigma}}_{\tilde{\boldsymbol{\beta}}}$  were estimated by the SAE model. We also drew county-level random effects from a normal distribution using the estimated random intercepts and their covariance. Let  $\hat{\mathbf{b}}_o$  be the estimated random intercepts of the counties observed in the 2016 NSCH dataset. Then, the bootstrap procedure drew  $\tilde{\mathbf{b}}_o^{rep}$  as

$$\tilde{\mathbf{b}}_o^{rep} \sim N(\hat{\mathbf{b}}_o, \hat{\boldsymbol{\Sigma}}_{\hat{\mathbf{b}}_o})$$

and  $\hat{\boldsymbol{\Sigma}}_{\hat{\mathbf{b}}_o}$  was the covariance of the estimated random intercepts  $\hat{\mathbf{b}}_o$ , both estimated in the SAE model. Additionally, the bootstrap procedure drew random intercepts of the counties missing from the 2016 NSCH dataset, denoted by  $\tilde{\mathbf{b}}_m^{rep}$ . Using properties of the multivariate normal distribution

$$\tilde{\mathbf{b}}_m^{rep} | \tilde{\mathbf{b}}_o^{rep} \sim N(\hat{\boldsymbol{\Sigma}}_{mo} \hat{\boldsymbol{\Sigma}}_o^{-1} (\tilde{\mathbf{b}}_o^{rep} - \hat{\mathbf{b}}_o), \hat{\boldsymbol{\Sigma}}_m - \hat{\boldsymbol{\Sigma}}_{mo} \hat{\boldsymbol{\Sigma}}_o^{-1} \hat{\boldsymbol{\Sigma}}_{om})$$

where  $\hat{\boldsymbol{\Sigma}} = \hat{\sigma}^2 \mathbf{W}^{-1} = \begin{bmatrix} \hat{\boldsymbol{\Sigma}}_o & \hat{\boldsymbol{\Sigma}}_{om} \\ \hat{\boldsymbol{\Sigma}}_{mo} & \hat{\boldsymbol{\Sigma}}_m \end{bmatrix}$ , and  $o$  indexed counties with observed data in NSCH while  $m$  indexed counties with data missing from the 2016 NSCH dataset.

By defining  $\mathbf{X}_k^{strata}$  as a design matrix of ones and zeros, indicating each of the 256 strata of the child-level variables (4 race/ethnicity levels, 2 gender levels, 8 age levels, and 4 education levels) for each county, and combining  $\tilde{\mathbf{b}}_o^{rep}$  and  $\tilde{\mathbf{b}}_m^{rep}$  into  $\tilde{\mathbf{b}}^{rep}$ , we can write:

$$\tilde{p}_{rgaek}^{rep} = \frac{\exp(\mathbf{X}^* \tilde{\boldsymbol{\beta}}^{rep} + \tilde{\mathbf{b}}^{rep})}{1 + \exp(\mathbf{X}^* \tilde{\boldsymbol{\beta}}^{rep} + \tilde{\mathbf{b}}^{rep})}$$

Note that  $\mathbf{X}^* = [\mathbf{X}_k^{strata} \mathbf{C}_{kS}]$ . Finally, we obtained 10,000 post-stratified obesity rates for each county.

$$\tilde{p}_k^{rep} = \frac{\sum_r \sum_g \sum_a \sum_e \tilde{p}_{rgaek}^{rep} POP_{rgaek}}{\sum_r \sum_g \sum_a \sum_e POP_{rgaek}}$$

We took the 2.5<sup>th</sup> and 97.5<sup>th</sup> percentiles of this Monte Carlo sample ( $\tilde{p}_k^{1, \dots, 10000}$ ) for each county  $k$  as the 95% CI of the county-level obesity prevalence.

## Data Sources

**Web Table 1** shows all available area-level variables for this study. The final variables retained in the model were based on a 5-fold cross-validation analysis seeking to maximize the model's predictive ability.

**Web Table 1: Available Area-level Variables from Policy Research Institutes and Governmental Agencies**

Variable Code	Variable Description	Data Source
<ul style="list-style-type: none"> <li>· rucc_2013</li> <li>· uic_2013</li> </ul>	Rurality: 2013 Urban Influence Codes (county level) and 2010 Rural-Urban Continuum Codes (census tract level)	U.S. Department of Agriculture (USDA)
<ul style="list-style-type: none"> <li>· percent_obese_2015</li> </ul>	Adult obesity rates: Estimates of adults with body mass index (BMI) greater than or equal to 30 kg/m <sup>2</sup>	County Health Rankings
<ul style="list-style-type: none"> <li>· foodenv_index_2015</li> </ul>	Food environment index: Index on food environment ranging from 0 (worst) to 10 (best) - assesses food insecurity/limited access to healthy foods	County Health Rankings
<ul style="list-style-type: none"> <li>· low_access_2015</li> </ul>	Low access to healthy food: Data on accessibility of healthy/affordable food through food retailers; density of grocery stores/supermarkets/convenience stores/fast food restaurants per 1000 persons; etc.	USDA – Food Access Research Atlas
<ul style="list-style-type: none"> <li>· food_desert_2015</li> </ul>	Food desert: Listing of low-income census tracts with limited access to healthy/affordable food	USDA – Food Access Research Atlas
<ul style="list-style-type: none"> <li>· sex_ratio_2016 (number of males per 100 females)</li> <li>· sex_ratio_2017 (number of males per 100 females)</li> </ul>	Aggregated population characteristics: Population distribution by sociodemographic category (e.g., by race, sex, median income,	American Community Survey (ACS)

Variable Code	Variable Description	Data Source
<ul style="list-style-type: none"> <li>· percent_less9th_2016 (education)</li> <li>· percent_9th12th_2016 (education)</li> <li>· percent_highsch_2016 (education)</li> <li>· percent_somecol_2016 (education)</li> <li>· percent_associ_2016 (education)</li> <li>· percent_bach_2016 (education)</li> <li>· percent_grad_2016 (education)</li> <li>· percent_less9th_2017 (education)</li> <li>· percent_9th12th_2017 (education)</li> <li>· percent_highsch_2017 (education)</li> <li>· percent_somecol_2017 (education)</li> <li>· percent_associ_2017 (education)</li> <li>· percent_bach_2017 (education)</li> <li>· percent_grad_2017 (education)</li> <li>· percent_belowpov_2016 (poverty)</li> <li>· percent_belowpov_2017 (poverty)</li> <li>· percent_househ_limitedEng_2016 (English speaking)</li> <li>· percent_househ_limitedEng_2017 (English speaking)</li> <li>· percent_white_2017 (race)</li> <li>· percent_black_2017 (race)</li> <li>· percent_native_2017 (race)</li> <li>· percent_asian_2017 (race)</li> <li>· percent_hawaiian_pacific_2017 (race)</li> <li>· percent_otherrace_2017 (race)</li> <li>· percent_hispanic_2017 (race)</li> <li>· percent_white_2016 (race)</li> </ul>	poverty level, English-speaking, educational attainment, etc.)	

Variable Code	Variable Description	Data Source
<ul style="list-style-type: none"> <li>· percent_black_2016 (race)</li> <li>· percent_native_2016 (race)</li> <li>· percent_asian_2016 (race)</li> <li>· percent_hawaiian_pacific_2016 (race)</li> <li>· percent_otherrace_2016 (race)</li> <li>· percent_hispanic_2016 (race)</li> <li>· percent_under18_2017 (age)</li> <li>· percent_highsch_orhigh_2016 (education)</li> <li>· percent_bach_orhigh_2016 (education)</li> <li>· percent_highsch_orhigh_2017 (education)</li> <li>· percent_bach_orhigh_2017 (education)</li> <li>· percent_nonwhite_2017 (race)</li> <li>· percent_nonwhite_2016 (race)</li> </ul>		
<ul style="list-style-type: none"> <li>· percent_phys_inact_2016 (physical activity)</li> <li>· schoolwelln_policy_2013 (school wellness)</li> <li>· schoolnutri_policy_2013 (school nutrition)</li> </ul>	Wellness program data: Data related to school nutrition, physical activity, breastfeeding policies, school wellness, insurance coverage, etc.	State of Obesity - Robert Wood Johnson Foundation
<ul style="list-style-type: none"> <li>· ever_breastfed_2015 (breastfeed)</li> </ul>	State-level data related to school nutrition, physical activity, breastfeeding policies, school wellness, insurance coverage, etc.	Centers for Disease Control and Prevention Breastfeeding Report Card
<ul style="list-style-type: none"> <li>· percent_unins_2015 (lack of insurance in adults)</li> </ul>	Insurance coverage estimates: Health insurance coverage estimates	County Health Rankings
<ul style="list-style-type: none"> <li>· medicaid_expansion_2019</li> <li>· medicaid_expansion_2016</li> </ul>	Medicaid expansion data: State Medicaid expansion status	Kaiser Family Foundation

Variable Code	Variable Description	Data Source
· percent_singlehouse_2015	Children in single-parent households: Estimates of children living in households with a single parent	County Health Rankings/ACS
· crime_rate_2015	Neighborhood safety: Rate of violent crime per 100,000 population	County Health Rankings
· percent_accessexercise_2015	Access to exercise opportunities: Percentage of individuals in a county who live reasonably close to a location for physical activity (parks, recreation facilities, gyms, etc.); number of recreation facilities per 1,000 persons; etc.	County Health Rankings; USDA
· school_prox_access_2016_2017 · rank_School_access · per_rank_School_access	Proximity and access to schools: Square mileage in each county/tract covered by ½ mile buffers around public schools (i.e., measures school walkability)	National Center for Education Statistics
· walkability_2010_2012 · rank_PopWeighted_Walk · per_rank_popweighted_walk	Walkability: Walkability index (0-20) for each block group, aggregated to county and tract level and weighted according to population distribution	Environmental Protection Agency - Smart Growth Smart Location Mapping Database
· number_primcare_2017 · number_primcare_2016 · number_pediatr_2017 · number_pediatr_2015	Primary care provider and pediatrician density: Number of providers (primary care and pediatrician, separately) per 100,000 residents in area <i>j</i>	Area Health Resource File



Variable Code	Variable Description	Data Source
· prior_authoriz_2015	Prior authorization policies: State-level data on prior authorization requirements for drug prescribing	Law Atlas
· 2017_foodinsec_rate (for adults) · 2017_child_foodinsec_rate (for children)	Hunger: Food insecurity describes a household's inability to provide enough food for every person to live an active, healthy life. Food insecurity is one way we can measure and assess the risk of hunger.	Feeding America
· 2016_child_uninsur_rate (lack of insurance in children)	Health insurance coverage estimates in children	SAHIE (Census Bureau)
· 2015_incar_rate · 2015_incar_rate_fem · 2015_incar_rate_male · 2015_incar_rate_asian · 2015_incar_rate_black · 2015_incar_rate_latino · 2015_incar_rate_native · 2015_incar_rate_white	Population incarcerated per 100,000 people: Adult population incarcerated per 100,000 people where incarceration means both jail and prison admission, overall, by race, by gender	Vera
· 2016_fundprop_fed · 2016_fundprop_state · 2016_fundprop_local	School Funding: Proportion of school funding coming from federal sources, from state sources, and from local sources, for each state	Census Bureau
· 2018_antibully_law_policy	Anti-bullying laws and policies: Whether each state has both anti-bullying laws AND policies or just laws OR policies	Department of Health and Human Services

## Results

**Web Table 2: SAE Model Results based on 2016 NSCH Dataset Including U.S. Children Aged 10-17 years**

Variable	Odds Ratio (OR)	Confidence Interval (CI)	P-Value <sup>a</sup>
Age			
10 years old	1.52	1.33, 1.74	<0.01
11 years old	1.55	1.36, 1.78	<0.01
12 years old	1.52	1.32, 1.74	<0.01
13 years old	1.31	1.14, 1.50	<0.01
14 years old	1.04	0.91, 1.20	0.56
15 years old	1.01	0.88, 1.15	0.93
16 years old	0.97	0.85, 1.12	0.71
17 years old	1.00	REF	REF
Percentage of Children in Single Parent Household (2015)	1.01	1.00, 1.02	0.06
Number Primary Care Providers by 100,000 Residents (2016)	1.00	1.00, 1.00	0.16
Rurality			
Metropolitan (Metro)	0.89	0.72, 1.09	0.25
Micropolitan (Micro)	1.14	0.92, 1.43	0.23
Rural	1.00	REF	REF
Adult Obesity Rate (2015)	1.01	0.99, 1.03	0.20
State School Wellness Policy (2016)	0.85	0.70, 1.03	0.09
Population Weighted Walkability Index (2016)	1.00	1.00, 1.01	0.03
Census Regional Division			
New England (NE)	1.31	0.88, 1.96	0.18
Mid Atlantic (MidA)	1.42	1.05, 1.92	0.02
East North Central (ENC)	1.23	0.93, 1.64	0.15
West North Central (WNC)	1.31	0.97, 1.78	0.08
South Atlantic (SA)	1.23	0.93, 1.63	0.14
East South Central (ESC)	1.44	1.04, 2.00	0.03
West South Central (WSC)	1.07	0.79, 1.45	0.66
Mountain (M)	1.00	0.72, 1.40	0.98
Pacific (P)	1.00	REF	REF

Variable	Odds Ratio (OR)	Confidence Interval (CI)	P-Value <sup>a</sup>
Gender × Race/Ethnicity × Parental Educational Attainment			
Female, Hispanic, Less than high school	3.25	2.42, 4.38	<0.01
Female, Hispanic, High school degree or GED	2.66	1.99, 3.56	<0.01
Female, Hispanic, Some college or technical school	3.72	2.78, 4.97	<0.01
Female, Hispanic, College degree or higher	1.69	1.24, 2.30	<0.01
Female, Non-Hispanic White, Less than high school	2.38	1.52, 3.72	<0.01
Female, Non-Hispanic White, High school degree or GED	1.75	1.32, 2.31	<0.01
Female, Non-Hispanic White, Some college or technical school	2.01	1.54, 2.62	<0.01
Female, Non-Hispanic White, College degree or higher	0.89	0.70, 1.14	0.37
Female, Non-Hispanic Black, Less than high school	2.60	1.48, 4.58	<0.01
Female, Non-Hispanic Black, High school degree or GED	2.72	1.89, 3.90	<0.01
Female, Non-Hispanic Black, Some college or technical school	6.13	4.41, 8.54	<0.01
Female, Non-Hispanic Black, College degree or higher	2.34	1.72, 3.19	<0.01
Female, Multi-Racial/Other Race, Less than high school	1.43	0.87, 2.36	0.16
Female, Multi-Racial/Other Race, High school degree or GED	1.89	1.21, 2.96	<0.01
Female, Multi-Racial/Other Race, Some college or technical school	2.62	1.80, 3.82	<0.01
Female, Multi-Racial/Other Race, College degree or higher	1.00	REF	REF
Male, Hispanic, Less than high school	5.50	4.10, 7.39	<0.01
Male, Hispanic, High school degree or GED	5.07	3.79, 6.76	<0.01
Male, Hispanic, Some college or technical school	2.05	1.50, 2.81	<0.01
Male, Hispanic, College degree or higher	1.89	1.41, 2.54	<0.01
Male, Non-Hispanic White, Less than high school	4.57	3.00, 6.97	<0.01
Male, Non-Hispanic White, High school degree or GED	2.43	1.85, 3.20	<0.01
Male, Non-Hispanic White, Some college or technical school	2.23	1.72, 2.90	<0.01
Male, Non-Hispanic White, College degree or higher	1.48	1.16, 1.89	<0.01
Male, Non-Hispanic Black, Less than high school	1.24	0.66, 2.34	0.50
Male, Non-Hispanic Black, High school degree or GED	3.20	2.31, 4.42	<0.01
Male, Non-Hispanic Black, Some college or technical school	3.73	2.70, 5.16	<0.01
Male, Non-Hispanic Black, College degree or higher	1.41	1.03, 1.94	0.03
Male, Multi-Racial/Other Race, Less than high school	2.02	1.03, 3.99	0.04
Male, Multi-Racial/Other Race, High school degree or GED	4.14	2.70, 6.33	<0.01
Male, Multi-Racial/Other Race, Some college or technical school	2.77	1.82, 4.22	<0.01

Variable	Odds Ratio (OR)	Confidence Interval (CI)	P-Value <sup>a</sup>
Male, Multi-Racial/Other Race, College degree or higher	1.62	1.19, 2.19	<0.01

<sup>a</sup> (All p-values are two-sided)

**Web Table 3: SAE Model Predictors based on 2016 NSCH Dataset Including U.S. Children Aged 10-17 years**

Fixed Child- and Area-Level Predictors	Number of Categories	P-Value <sup>a</sup>
Race/Ethnicity	4	<0.0001
Gender	2	0.006
Age	8	<0.0001
Parental Educational Achievement	4	<0.0001
Gender × Race/Ethnicity	8	<0.0001
Parental Educational Achievement × Race/Ethnicity	16	<0.0001
Gender × Parental Educational Achievement	8	0.0002
Gender × Parental Educational Achievement × Race/Ethnicity	32	<0.0001
Census Regional Division	9	0.11
Percentage of Children in Single Parent Household (2015)	Not Applicable	0.06
Number Primary Care Providers by 100,000 Residents (2016)	Not Applicable	0.16
Rurality Status	3	0.02
Adult Obesity Rate (2015)	Not Applicable	0.20
State School Wellness Policy (2016)	2	0.09
Population Weighted Walkability Index (2016)	Not Applicable	0.03

<sup>a</sup> P-Values are for Type III tests examining the significance of a predictor with all the other predictors in the model

**Web Table 4: Childhood Overweight/Obesity Estimates and 95% Confidence Intervals (95% CI) for all Counties Identified as Significantly Below/Above the National Rate or Having a Significantly Higher Rate than Expected Based on Fixed Effects, based on 2016 NSCH Dataset Including U.S. Children Aged 10-17 years**

County, State	Rate %	Rate 95% CI	Category (Below/Above National Rate, High Rate Given Fixed Effects)
U.S.	30.7	27.0, 34.9	
Rockwall, TX	80.9	63.8, 91.9	Significantly Above National Rate, Significantly High Rate Given Fixed Effects
Webb, TX	80.7	65.2, 91.5	Significantly Above National Rate, Significantly High Rate Given Fixed Effects
Madera, CA	75.4	55.6, 89.4	Significantly Above National Rate, Significantly High Rate Given Fixed Effects
Coryell, TX	67.3	49.0, 82.3	Significantly Above National Rate, Significantly High Rate Given Fixed Effects
Dougherty, GA	64.4	45.0, 80.6	Significantly Above National Rate
Manatee, FL	59.0	42.3, 74.6	Significantly High Rate Given Fixed Effects
Volusia, FL	58.0	40.9, 73.7	Significantly High Rate Given Fixed Effects
Hudson, NJ	57.9	41.5, 73.4	Significantly High Rate Given Fixed Effects
Hidalgo, TX	56.7	45.7, 67.4	Significantly Above National Rate, Significantly High Rate Given Fixed Effects
Broward, FL	55.0	42.5, 67.0	Significantly Above National Rate, Significantly High Rate Given Fixed Effects
Tarrant, TX	51.1	39.5, 62.7	Significantly Above National Rate, Significantly High Rate Given Fixed Effects
Solano, CA	50.3	35.0, 65.8	Significantly High Rate Given Fixed Effects
San Joaquin, CA	49.4	35.4, 63.4	Significantly High Rate Given Fixed Effects
Orange, FL	48.3	36.8, 59.9	Significantly High Rate Given Fixed Effects
Riverside, CA	43.3	31.7, 55.7	Significantly High Rate Given Fixed Effects
Honolulu, HI	21.0	16.8, 25.8	Significantly Below National Rate
Travis, TX	16.1	9.4, 25.2	Significantly Below National Rate
New York, NY	13.2	5.5, 25.1	Significantly Below National Rate
Washington, OR	12.8	5.9, 23.1	Significantly Below National Rate
Lake, FL	12.3	5.1, 23.6	Significantly Below National Rate
Alameda, CA	12.1	6.1, 20.6	Significantly Below National Rate
Utah, UT	11.3	4.8, 21.8	Significantly Below National Rate
Sacramento, CA	11.3	5.6, 19.4	Significantly Below National Rate
Trumbull, OH	10.8	3.5, 23.8	Significantly Below National Rate
Ellis, TX	10.7	3.4, 23.8	Significantly Below National Rate
Contra Costa, CA	10.5	5.4, 17.7	Significantly Below National Rate

Kings, CA	10.2	3.3, 22.8	Significantly Below National Rate
Macoupin, IL	9.7	2.9, 22.6	Significantly Below National Rate
Chambers, TX	9.6	3.0, 22.2	Significantly Below National Rate
St Johns, FL	9.6	3.2, 20.9	Significantly Below National Rate
Hamilton, IN	9.4	3.2, 20.8	Significantly Below National Rate
Boone, IL	9.1	2.9, 20.3	Significantly Below National Rate
Placer, CA	9.0	2.6, 21.7	Significantly Below National Rate
Comal, TX	8.7	3.3, 17.6	Significantly Below National Rate
Sonoma, CA	7.9	2.5, 17.9	Significantly Below National Rate
Tulare, CA	7.9	2.7, 17.4	Significantly Below National Rate
Ector, TX	7.8	2.7, 17.0	Significantly Below National Rate
San Mateo, CA	7.0	2.2, 16.1	Significantly Below National Rate

All results use a false discovery rate (FDR) at a significance level of  $\alpha=0.05$ .

**Web Table 5: Overweight/Obesity Rates in the U.S. and at the State Level, based on 2016 NSCH Dataset Including U.S. Children Aged 10-17 years**

State	Rate %	Rate 95% CI	Number of Counties	Interquartile Range	Counties with Rate Significantly Below National Rate, n	Counties with Rate Significantly Above National Rate, n	Counties with Rate Significantly Lower Given Predictors, n	Counties with Rate Significantly Higher Given Predictors, n
U.S.	30.7	27.0, 34.9	3143	2.9	23	8	0	14
AK	26.9	19.4, 36.3	29	5.9	0	0	0	0
AL	36.5	31.1, 42.3	67	3.9	0	0	0	0
AR	32.5	27.1, 38.4	75	3.8	0	0	0	0
AZ	25.4	17.0, 37.0	15	7.0	0	0	0	0
CA	29.6	18.8, 42.6	58	9.01	8	1	0	4
CO	23.1	18.2, 29.0	64	3.8	0	0	0	0
CT	29.1	21.0, 38.4	8	6.0	0	0	0	0
DC	31.5	17.8, 49.9	1	11.7	0	0	0	0
DE	30.9	21.8, 41.7	3	6.8	0	0	0	0
FL	33.5	27.7, 40.6	67	4.5	2	1	0	4
GA	30.9	27.1, 34.8	159	2.7	0	1	0	0
HI	23.2	18.7, 28.5	5	3.3	1	0	0	0
IA	31.0	26.4, 36.1	99	3.4	0	0	0	0
ID	25.9	19.8, 33.2	44	4.6	0	0	0	0
IL	28.7	18.9, 41.3	102	8.2	2	0	0	0
IN	33.5	29.2, 38.0	92	3.1	1	0	0	0
KS	29.9	24.8, 35.6	105	3.7	0	0	0	0
KY	36.0	30.7, 41.6	120	3.8	0	0	0	0
LA	33.1	27.3, 39.2	64	4.2	0	0	0	0
MA	26.5	19.5, 34.7	14	5.2	0	0	0	0
MD	31.4	26.4, 36.9	24	3.5	0	0	0	0
ME	28.7	20.7, 38.3	16	6.1	0	0	0	0
MI	31.0	26.3, 36.4	83	3.5	0	0	0	0
MN	27.5	22.9, 32.8	87	3.4	0	0	0	0
MO	30.3	25.0, 35.4	115	3.3	0	0	0	0
MS	39.0	32.7, 45.6	82	4.5	0	0	0	0
MT	24.1	18.2, 31.3	56	4.5	0	0	0	0
NC	32.8	28.9, 37.0	100	2.8	0	0	0	0
ND	30.9	24.4, 38.6	53	4.9	0	0	0	0
NE	29.9	24.1, 36.7	93	4.4	0	0	0	0

NH	25.3	17.4, 35.2	10	6.2	0	0	0	0
NJ	32.9	27.8, 38.5	21	3.7	0	0	0	1
NM	27.1	21.0, 34.6	33	4.6	0	0	0	0
NV	30.2	21.9, 40.6	17	6.5	0	0	0	0
NY	32.3	26.6, 38.5	62	4.1	1	0	0	0
OH	31.4	27.3, 35.7	88	2.9	1	0	0	0
OK	29.3	24.3, 34.8	77	3.6	0	0	0	0
OR	22.5	17.7, 28.4	36	3.7	1	0	0	0
PA	30.1	25.7, 35.0	67	3.2	0	0	0	0
RI	32.8	21.6, 45.6	5	8.6	0	0	0	0
SC	31.2	26.7, 35.9	46	3.2	0	0	0	0
SD	32.0	25.8, 39.3	66	4.6	0	0	0	0
TN	36.1	30.6, 41.8	95	3.9	0	0	0	0
TX	33.6	28.2, 39.4	254	3.8	5	5	0	5
UT	20.7	15.4, 27.2	29	4.1	1	0	0	0
VA	27.7	23.0, 32.9	134	3.4	0	0	0	0
VT	26.9,	18.8, 37.3	14	6.5	0	0	0	0
WA	26.0	20.8, 32.1	39	3.9	0	0	0	0
WI	30.5	26.0, 35.5	72	3.3	0	0	0	0
WV	33.0	27.5, 39.0	55	4.0	0	0	0	0
WY	26.2	19.1, 34.6	23	5.5	0	0	0	0



**Web Table 6: Childhood Overweight/Obesity Estimates for Los Angeles and Dallas Counties, based on 2016 NSCH Dataset Including U.S. Children Aged 10-17 years**

Type of estimate	Fixed and random effects			Fixed effects only		
County, State	Rate, %	95% CI, %	CI Length, %	Rate, %	95% CI, %	CI Length, %
Los Angeles, CA	42.7	11.9, 78.8	66.9	37.8	12.5, 69.3	56.8
Dallas, TX	44.4	31.3, 57.9	26.5	30.3	23.0, 38.1	15.0

Shown are the overall estimates, 95% confidence intervals (95% CI) and confidence interval length (CI Length) for the full estimates (using fixed and random effects) and only using covariate data (fixed effects only). Of note is the large difference in fixed effect CI length between the counties.

**Web Table 7: Estimated Child Overweight/Obesity Rates by Race/Ethnic Group, Gender, and Parental Education Attainment for Los Angeles and Dallas Counties, based on 2016 NSCH Dataset Including U.S. Children Aged 10-17 years**

County, State	Group	Group Prevalence, %	Estimated Group Rate, (CI, CI Length), %	Estimated Group Rate with County Random Effect, (CI, CI Length), %	Difference in CI Length, %
Los Angeles, CA	Hispanic, Male, Less than High School	5.5	1.6, (0.6-2.9, 2.3)	1.7, (0.5-3.0, 2.5)	0.2
Los Angeles, CA	Non-Hispanic White, Male, Less than High School	0.5	0.1, (0.0-0.2, 0.2)	0.1, (0.0-0.3, 0.2)	0.0
Los Angeles, CA	Non-Hispanic Black, Male, Less than High School	0.2	0.03, (0.0-0.1, 0.1)	0.0, (0.0-0.1, 0.1)	0.0
Los Angeles, CA	Multi-racial/Other race, Male, Less than High School	1.3	0.25, (0.1-0.6, 0.5)	0.3, (0.1-0.6, 0.5)	0.1
Los Angeles, CA	Hispanic, Female, Less than High School	5.3	1.25, (0.3-2.5, 2.2)	1.4, (0.3-2.8, 2.4)	0.2
Los Angeles, CA	Non-Hispanic White, Female, Less than High School	0.4	0.09, (0.0-0.2, 0.2)	0.1, (0.0-0.2, 0.2)	0.0
Los Angeles, CA	Non-Hispanic Black, Female, Less than High School	0.2	0.1, (0.0-0.1, 0.1)	0.1, (0.0-0.1, 0.1)	0.0
Los Angeles, CA	Multi-racial/Other race, Female, Less than High School	1.3	0.19, (0.0-0.5, 0.4)	0.2, (0.0-0.6, 0.5)	0.1
Los Angeles, CA	Hispanic, Male, High School or GED	4.4	1.26, (0.4-2.3, 1.9)	1.4, (0.4-2.4, 2.01)	0.1
Los Angeles, CA	Non-Hispanic White,	1.5	0.31, (0.1-0.7, 0.6)	0.4, (0.1-0.7, 0.7)	0.1

	Male, High School or GED				
Los Angeles, CA	Non-Hispanic Black, Male, High School or GED	0.5	0.1, (0.0-0.2, 0.2)	0.1, (0.0-0.2, 0.2)	0.0
Los Angeles, CA	Multi-racial/Other race, Male, High School or GED	1.9	0.5, (0.2-0.9, 0.8)	0.5, (0.2-1.0, 0.9)	0.1
Los Angeles, CA	Hispanic, Female, High School or GED	4.2	0.9, (0.2-1.9, 1.7)	1.0, (0.2-2.1, 1.9)	0.2
Los Angeles, CA	Non-Hispanic White, Female, High School or GED	1.4	0.2, (0.1-0.6, 0.5)	0.3, (0.1-0.7, 0.6)	0.1
Los Angeles, CA	Non-Hispanic Black, Female, High School or GED	0.5	0.1, (0.0-0.2, 0.2)	0.1, (0.0-0.3, 0.2)	0.0
Los Angeles, CA	Multi-racial/Other race, Female, High School or GED	1.8	0.3, (0.0-0.7, 0.7)	0.4, (0.1-0.8, 0.8)	0.1
Los Angeles, CA	Hispanic, Male, Some College	3.9	0.7, (0.2-1.6, 1.5)	0.8, (0.2-1.8, 1.7)	0.2
Los Angeles, CA	Non-Hispanic White, Male, Some College	2.7	0.5, (0.1-1.2, 1.0)	0.6, (0.1-1.3, 1.2)	0.2
Los Angeles, CA	Non-Hispanic Black, Male, Some College	0.7	0.2, (0.1-0.4, 0.3)	0.2, (0.1-0.4, 0.3)	0.0
Los Angeles, CA	Multi-racial/Other race, Male, Some College	2.8	0.6, (0.2-1.32, 1.1)	0.7, (0.2-1.4, 1.3)	0.1
Los Angeles, CA	Hispanic,	3.7	0.9, (0.3-1.8, 1.6)	1.0, (0.3-2.0, 1.7)	0.2

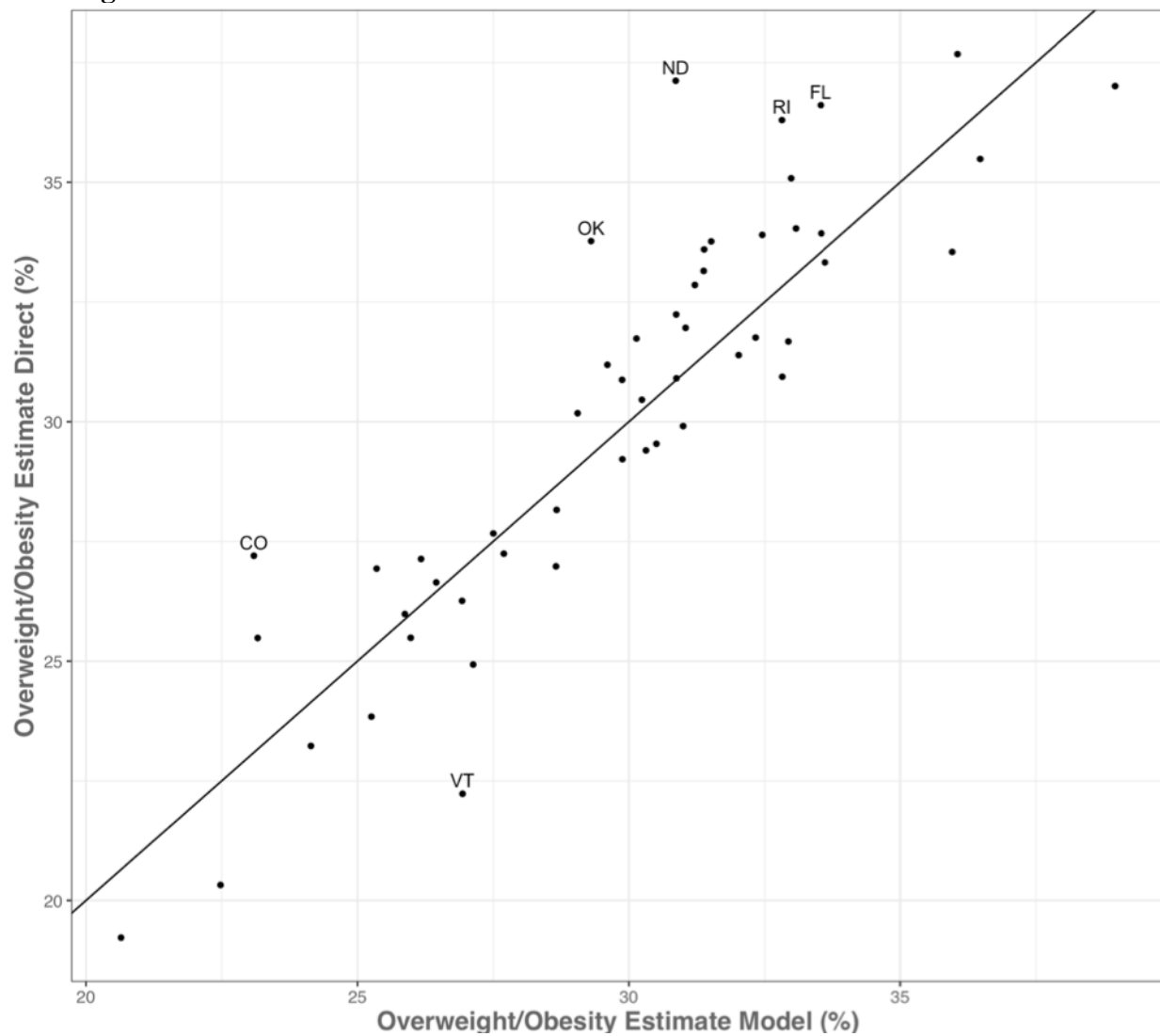
	Female, Some College				
Los Angeles, CA	Non-Hispanic White, Female, Some College	2.5	0.5, (0.1-1.1, 1.0)	0.5, (0.1-1.2, 1.1)	0.2
Los Angeles, CA	Non-Hispanic Black, Female, Some College	0.7	0.2, (0.1-0.3, 0.3)	0.2, (0.1-0.4, 0.3)	0.0
Los Angeles, CA	Multi-racial/Other race, Female, Some College	2.7	0.6, (0.2-1.2, 1.1)	0.7, (0.2-1.4, 1.2)	0.1
Los Angeles, CA	Hispanic, Male, College or Higher	5.7	1.0, (0.2-2.3, 2.1)	1.2, (0.2-2.7, 2.4)	0.3
Los Angeles, CA	Non-Hispanic White, Male, College or Higher	11.1	1.7, (0.4-4.2, 3.8)	2.0, (0.4-4.9, 4.5)	0.7
Los Angeles, CA	Non-Hispanic Black, Male, College or Higher	1.1	0.2, (0.0-0.4, 0.4)	0.2, (0.0-0.5, 0.4)	0.1
Los Angeles, CA	Multi-racial/Other race, Male, College or Higher	7.5	1.2, (0.3-2.9, 2.6)	1.4, (0.3-3.3, 3.1)	0.5
Los Angeles, CA	Hispanic, Female, College or Higher	5.5	0.9, (0.2-2.2, 2.0)	1.1, (0.2-2.5, 2.3)	0.3
Los Angeles, CA	Non-Hispanic White, Female, College or Higher	10.5	1.2, (0.2-3.1, 2.9)	1.4, (0.2-3.9, 3.7)	0.7
Los Angeles, CA	Non-Hispanic Black, Female, College or Higher	1.0	0.2, (0.1-0.4, 0.4)	0.2, (0.1-0.5, 0.4)	0.1
Los Angeles, CA	Multi-racial/Other race,	7.1	0.9, (0.2-2.3, 2.1)	1.0, (0.2-2.7, 2.6)	0.5

	Female, College or Higher				
Dallas, TX	Hispanic, Male, Less than High School	5.8	1.5, (0.8-2.4, 1.6)	1.9, (1.0-3.0, 2.0)	0.4
Dallas, TX	Non-Hispanic White, Male, Less than High School	0.4	0.1, (0.1-0.2, 0.1)	0.1, (0.1-0.2, 0.1)	0.0
Dallas, TX	Non-Hispanic Black, Male, Less than High School	0.6	0.1, (0.0-0.1, 0.1)	0.1, (0.0-0.2, 0.2)	0.1
Dallas, TX	Multi-racial/Other race, Male, Less than High School	0.6	0.1, (0.0-0.2, 0.1)	0.1, (0.1-0.2, 0.2)	0.1
Dallas, TX	Hispanic, Female, Less than High School	5.5	1.1, (0.5-1.8, 1.3)	1.5, (0.7-2.5, 1.7)	0.5
Dallas, TX	Non-Hispanic White, Female, Less than High School	0.4	0.1, (0.0-0.1, 0.1)	0.1, (0.0-0.2, 0.1)	0.0
Dallas, TX	Non-Hispanic Black, Female, Less than High School	0.6	0.1, (0.1-0.2, 0.1)	0.2, (0.1-0.3, 0.2)	0.1
Dallas, TX	Multi-racial/Other race, Female, Less than High School	0.6	0.1, (0.0-0.1, 0.1)	0.1, (0.0-0.2, 0.2)	0.1
Dallas, TX	Hispanic, Male, High School or GED	5.3	1.3, (0.7-2.1, 1.4)	1.7, (0.9-2.7, 1.8)	0.4
Dallas, TX	Non-Hispanic White, Male, High School or GED	2.1	0.3, (0.2-0.6, 0.4)	0.5, (0.2-0.8, 0.6)	0.2
Dallas, TX	Non-Hispanic Black,	2.1	0.4, (0.2-0.6, 0.4)	0.6, (0.3-0.9, 0.6)	0.2

	Male, High School or GED				
Dallas, TX	Multi-racial/Other race, Male, High School or GED	1.0	0.2, (0.1-0.4, 0.3)	0.3, (0.2-0.5, 0.3)	0.1
Dallas, TX	Hispanic, Female, High School or GED	5.0	0.9, (0.4-1.5, 1.1)	1.3, (0.6-2.1, 1.5)	0.5
Dallas, TX	Non-Hispanic White, Female, High School or GED	2.0	0.3, (0.1-0.4, 0.3)	0.4, (0.2-0.7, 0.5)	0.2
Dallas, TX	Non-Hispanic Black, Female, High School or GED	2.0	0.5, (0.2-0.7, 0.5)	0.6, (0.3-0.9, 0.6)	0.1
Dallas, TX	Multi-racial/Other race, Female, High School or GED	1.0	0.1, (0.1-0.3, 0.2)	0.2, (0.1-0.4, 0.3)	0.1
Dallas, TX	Hispanic, Male, Some College	2.9	0.4, (0.2-0.7, 0.6)	0.6, (0.3-1.1, 0.9)	0.3
Dallas, TX	Non-Hispanic White, Male, Some College	3.1	0.5, (0.2-0.8, 0.6)	0.7, (0.3-1.2, 0.9)	0.3
Dallas, TX	Non-Hispanic Black, Male, Some College	2.4	0.5, (0.3-0.8, 0.6)	0.7, (0.4-1.1, 0.7)	0.2
Dallas, TX	Multi-racial/Other race, Male, Some College	1.2	0.2, (0.1-0.4, 0.3)	0.3, (0.1-0.5, 0.4)	0.1
Dallas, TX	Hispanic, Female, Some College	2.8	0.6, (0.3-1.0, 0.7)	0.8, (0.4-1.3, 0.9)	0.2
Dallas, TX	Non-Hispanic White,	2.9	0.4, (0.2-0.7, 0.5)	0.6, (0.3-1.1, 0.8)	0.3

	Female, Some College				
Dallas, TX	Non-Hispanic Black, Female, Some College	2.4	0.5, (0.3-0.8, 0.5)	0.7, (0.4-1.1, 0.7)	0.2
Dallas, TX	Multi-racial/Other race, Female, Some College	1.2	0.2, (0.1-0.4, 0.3)	0.3, (0.1-0.5, 0.4)	0.1
Dallas, TX	Hispanic, Male, College or Higher	3.6	0.5, (0.2-0.9, 0.6)	0.8, (0.3-1.3, 1.0)	0.4
Dallas, TX	Non-Hispanic White, Male, College or Higher	13.7	1.5, (0.7-2.7, 2.0)	2.5, (1.1-4.4, 3.3)	1.3
Dallas, TX	Non-Hispanic Black, Male, College or Higher	2.7	0.3, (0.1-0.5, 0.4)	0.5, (0.2-0.8, 0.6)	0.3
Dallas, TX	Multi-racial/Other race, Male, College or Higher	3.7	0.4, (0.2-0.8, 0.6)	0.7, (0.3-1.3, 01.0)	0.4
Dallas, TX	Hispanic, Female, College or Higher	3.4	0.4, (0.2-0.8, 0.6)	0.7, (0.3-1.2, 0.9)	0.3
Dallas, TX	Non-Hispanic White, Female, College or Higher	12.8	1.0, (0.4-1.7, 1.3)	1.6, (0.7-3.1, 2.5)	1.2
Dallas, TX	Non-Hispanic Black, Female, College or Higher	2.6	0.4, (0.2-0.7, 0.5)	0.6, (0.3-1.0, 0.7)	0.2
Dallas, TX	Multi-racial/Other race, Female, College or Higher	3.6	0.3, (0.1-0.5, 0.4)	0.5, (0.2-0.9, 0.7)	0.3

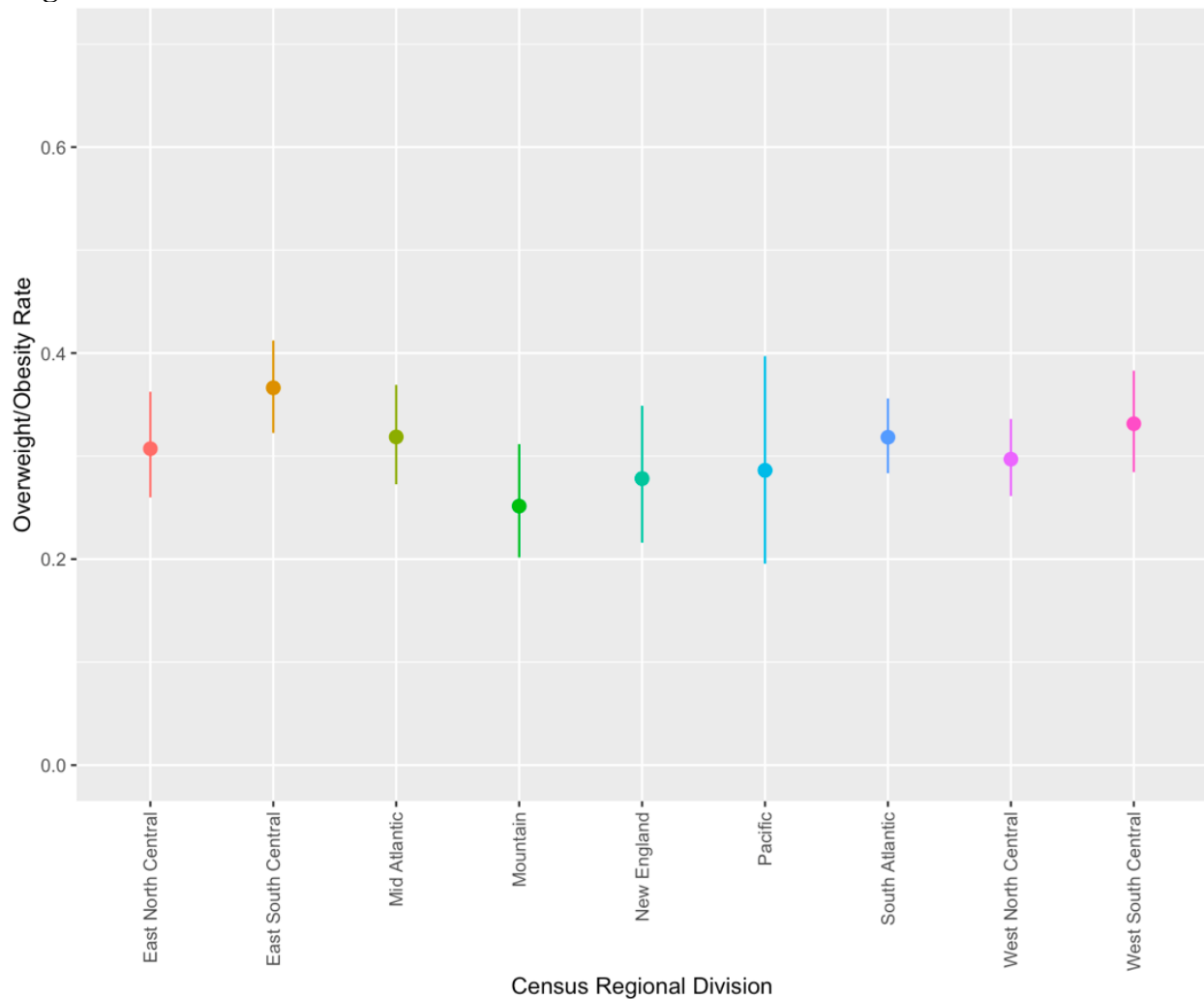
**Web Figure 1: 2016 NSCH State-Level Model Validation Results**



This figure presents model-estimated childhood overweight/obesity rates compared against direct estimates of childhood overweight/obesity.

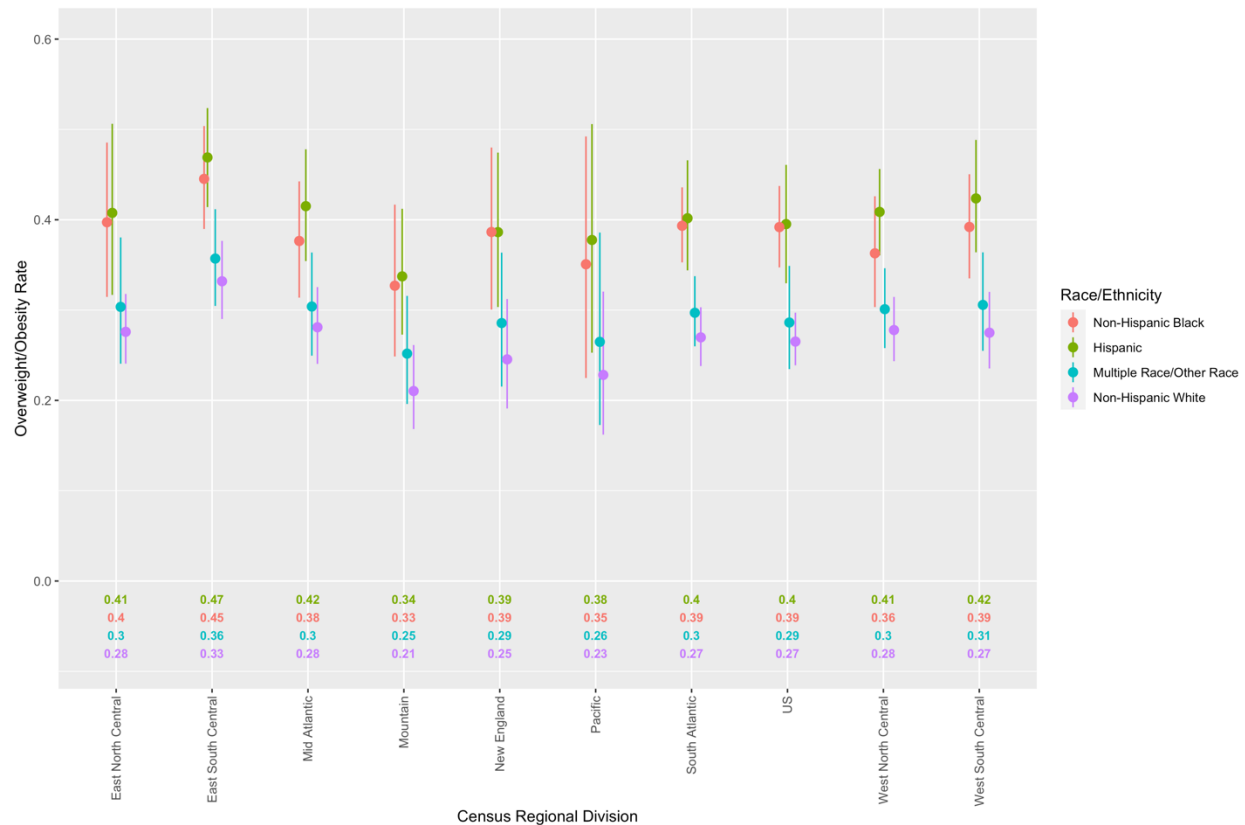


**Web Figure 2: 2016 Estimates of Childhood Overweight/Obesity Rates at the Census Regional Division Level**



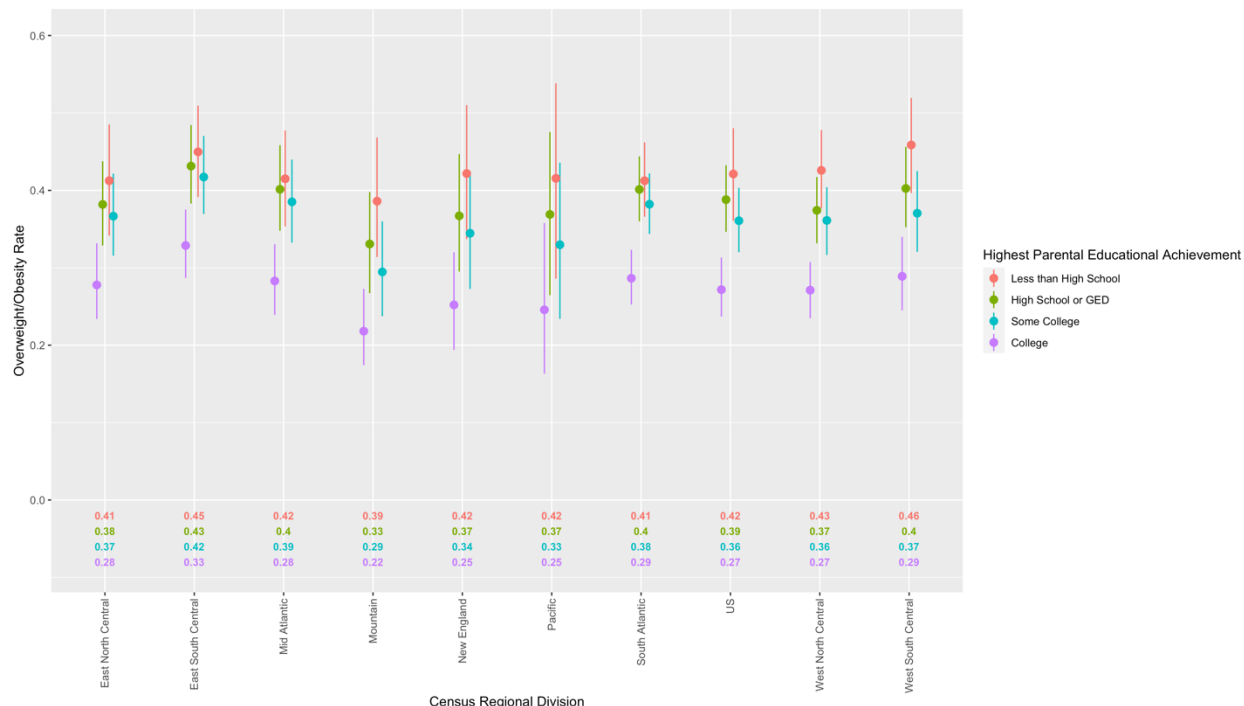
This figure presents estimated childhood overweight/obesity rates for each Census Regional Division, using 2016 NSCH data.

**Web Figure 3: 2016 Estimates of Childhood Overweight/Obesity Rates by Child Race/Ethnicity**



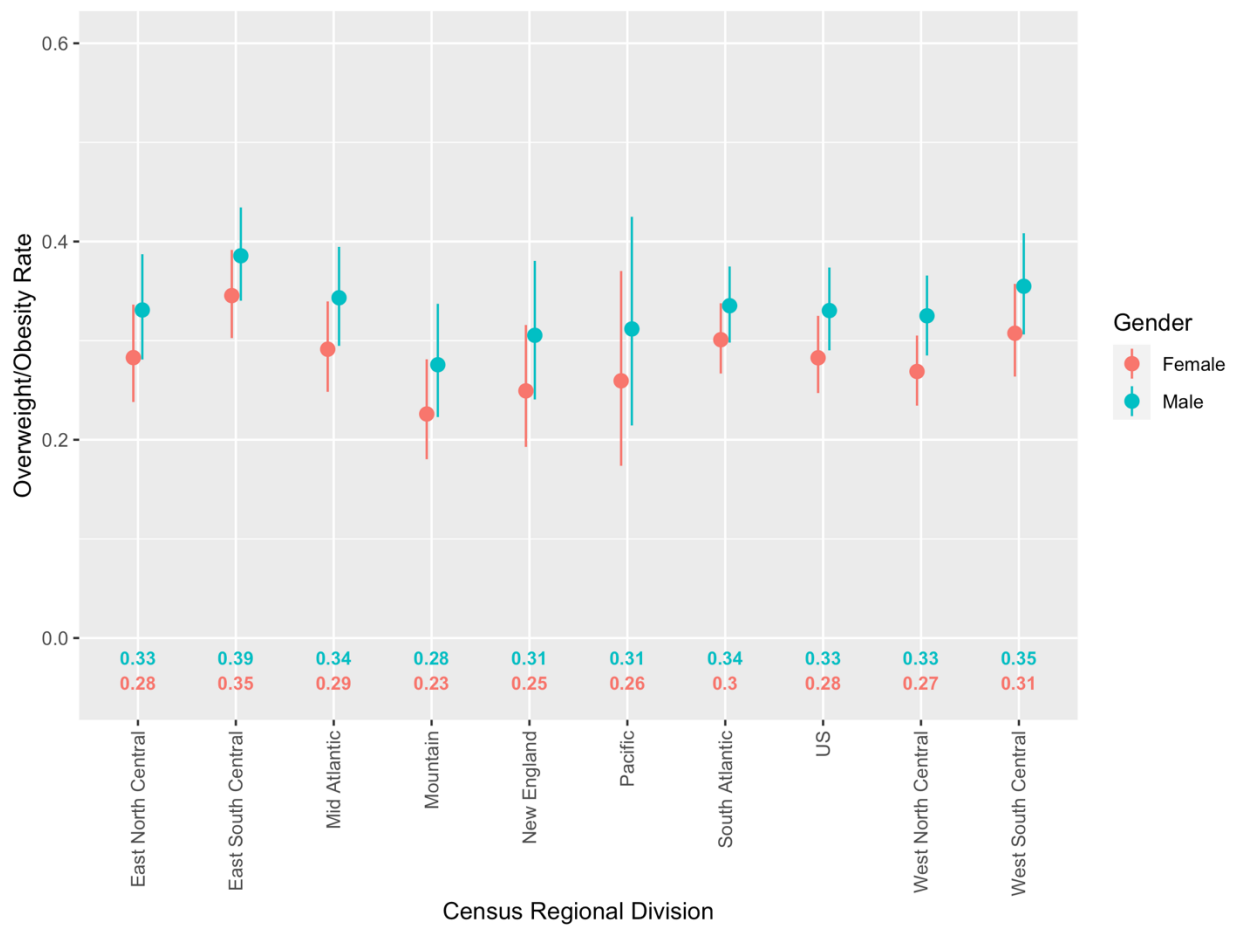
This figure presents estimated childhood overweight/obesity rates for each race/ethnicity group using 2016 NSCH data. The red points represent estimated overweight/obesity rates for Non-Hispanic Black children. The green points represent estimated overweight/obesity rates for Hispanic children. The blue points represent estimated overweight/obesity rates for children of multiple or other race. The purple points represent estimated overweight/obesity rates for Non-Hispanic White children.

**Web Figure 4: 2016 Estimates of Childhood Overweight/Obesity Rates by Highest Parental Educational Achievement**



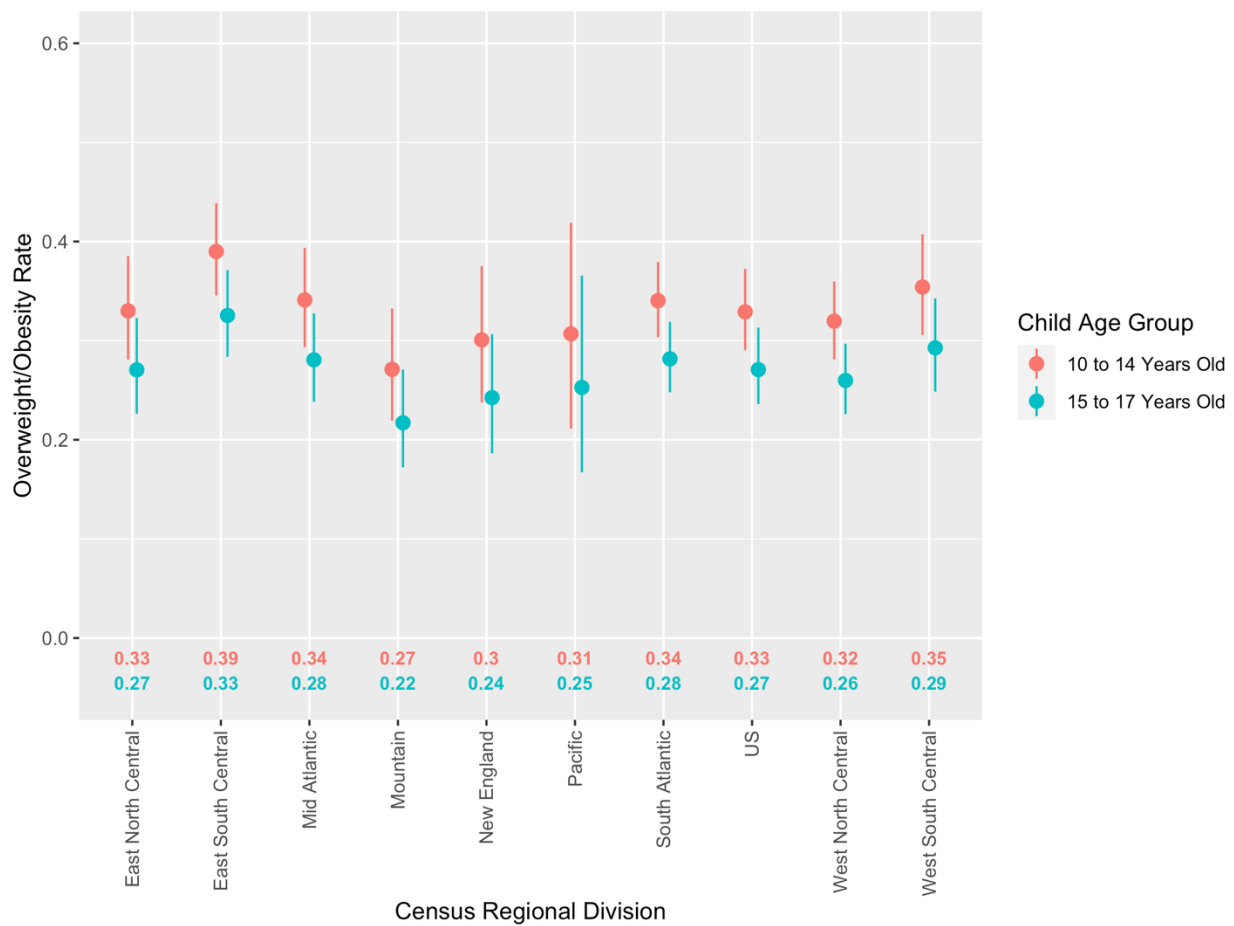
This figure presents estimated childhood overweight/obesity rates for each level of parental highest education using 2016 NSCH data. The red points represent estimated overweight/obesity rates for children whose parent's highest education is some high school. The green points represent estimated overweight/obesity rates for children whose parent's highest education is high school or GED. The blue points represent estimated overweight/obesity rates for children whose parent's highest education is some college. The purple points represent estimated overweight/obesity rates for children whose parent's highest education is college or higher.

**Web Figure 5: 2016 Estimates of Childhood Overweight/Obesity Rates by Child Gender**



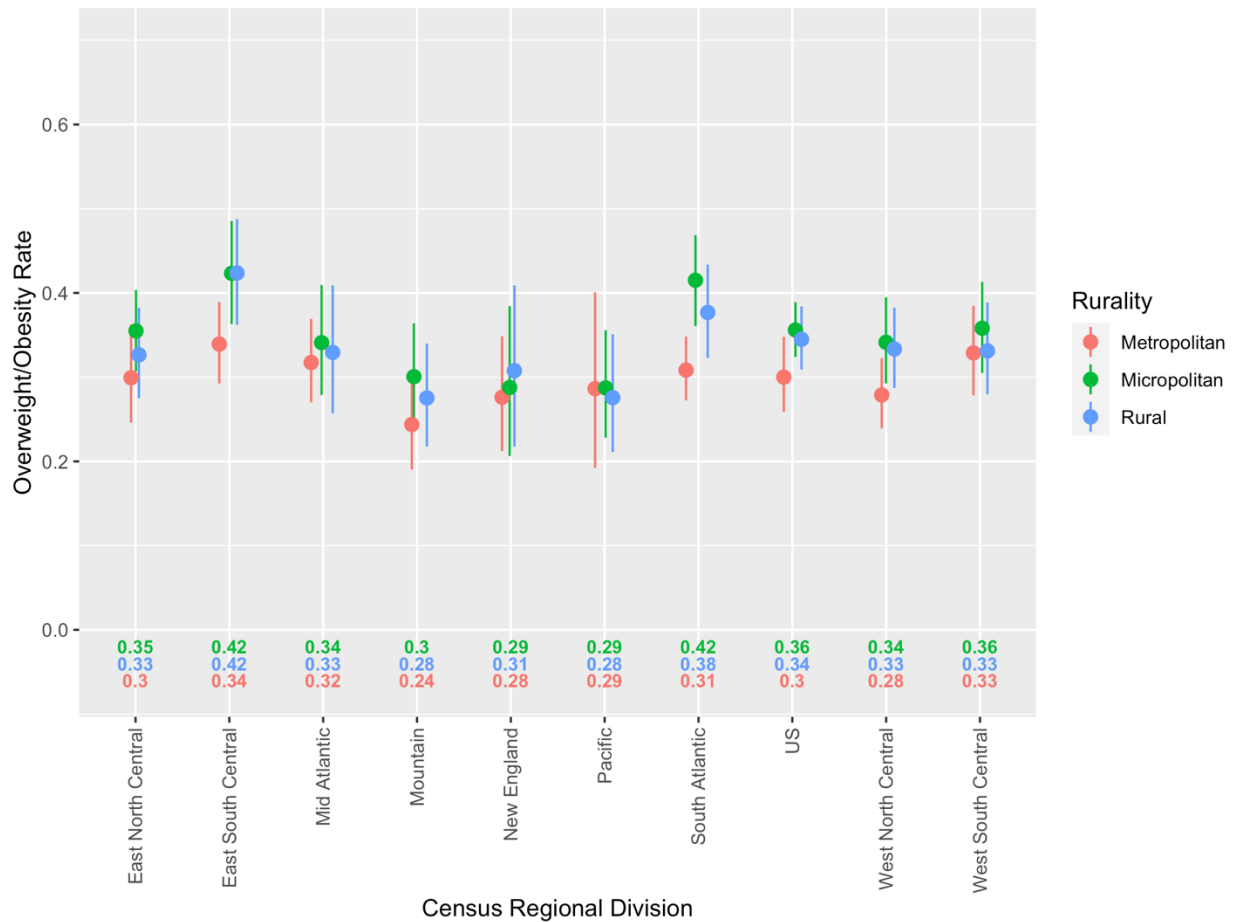
This figure presents estimated childhood overweight/obesity rates for each gender group using 2016 NSCH data. The red points represent estimated overweight/obesity rates for female children. The blue points represent estimated overweight/obesity rates for male children.

**Web Figure 6: 2016 Estimates of Childhood Overweight/Obesity Rates by Child Age**



This figure presents estimated childhood overweight/obesity rates for each age group using 2016 NSCH data. The red points represent estimated overweight/obesity rates for children between the ages of 10 to 14. The blue points represent estimated overweight/obesity rates for children between the ages of 15 to 17.

**Web Figure 7: 2016 Estimates of Childhood Overweight/Obesity Rates by Child Rurality Status**



This figure presents estimated childhood overweight/obesity rates for each rurality group using 2016 NSCH data. The red points represent estimated overweight/obesity rates for children residing in metropolitan areas. The green points represent estimated overweight/obesity rates for children residing in micropolitan areas. The blue points represent estimated overweight/obesity rates for children residing in rural areas.

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